SPECIAL REPORT

22 December 1949

REGISTRATION ACCURACY TESTS OF THE FAIRCHILD RADAR RECORDING 35 MM. CAMERA

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CONTRACTOR: High Altitude Observatory of Harvard University and University of Colorado, Boulder, Colorado.

PROJECT TITLE: Development and Construction of High Precision Optical Instruments and Equipment for Use in Solar Research, Including an Equatorial Table and an Eight-inch Coronagraph, or its Equivalent.

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ABSTRACT

These tests were made to evaluate the accuracy of registration attainable when we use the Fairchild Radar Recording Camera with the Mitchell Background Projector mechanism for high-accuracy registration and reduction equipment for planned solar studies. The tests revealed that a modified camera will be suitable for much of our work, but that the camera unmodified does not provide satisfactory operation for most of the planned uses.

OUTLINE

I. INTRODUCTION.

The Fairchild Radar Recording Camera presents many attractive features for us as a recording camera for solar studies. Its ease of film changing and its compactness especially recommend it. On the other hand the solenoid operation is abrupt, producing a substantial impact at the film advance cycle, and the film claw in its return across the sprocket holes rests on the film heavily enough, it seems, perhaps to damage or enlarge the sprocket holes enough to be detrimental when high-accuracy registration is involved.

To evaluate some of these factors we have conducted the tests reported here. We wish to have cameras in which it is possible for us to return a piece of exposed 35 mm. motion picture film to a film or projector accuracy with a differential displacement from frame to frame of $\pm$ 0.0002 inches on the average, and without any appreciable number of values departing from other values within a long run by more than three to four times this amount. The quantity measuring the difference between the largest and smallest position readings we have called the "range" in our tests below. Tolerances should apply in both co-ordinates in the film plane, if we are to use the cameras to provide a basic reference system on our films, dependent upon the position the film assumes in the reference frame of the film analysis projector. If we succeed in attaining these limits the manpower problem for reduction of prominence motion data will be greatly lessened.

In the tests that follow we have tried out two versions of the Fairchild camera. One we have modified so that it operates smoothly by motor from a 110 volt AC supply, without damaging impact forces. The other is an unmodified 28 volt DC solenoid version of the camera, just as used for radar scope recording.

II. THE TESTING PROCEDURE.

Two different cameras were used in these tests. One (ONR-7 in our designation,) has been substantially modified and has now position pins; the other (ONR-3) is unmodified.

For our tests here, as was in the case of the Mitchell mechanism,(1*) we printed on each frame a shadow image of a criss-cross hair pattern, rigidly placed 2 mm. in front of the film emulsion during exposure. As before, the film used was Eastman Safety Positive Film punched with Bell and Howell perforations. Unlike the position pins of the Mitchell camera, which are more or less form fitting, the pins of the Fairchild camera, both the modified and the unmodified ones, are circular in cross section. The diameter of these cylindrical pins is so dimensioned that they touch the straight edges of the perforations at

(1*) Special Report, 30 April 1949, "An Investigation on the Accuracy of the Mitchell Motion Picture Camera as an Instrument for the Registration and Reduction of Solar Prominence Photographs," Dr. Ch'ing-Sung Yü, Research Staff, High Altitude Observatory, Boulder, Colorado.

two points in the X-direction (along the strip of film) as shown in Figure 1a.

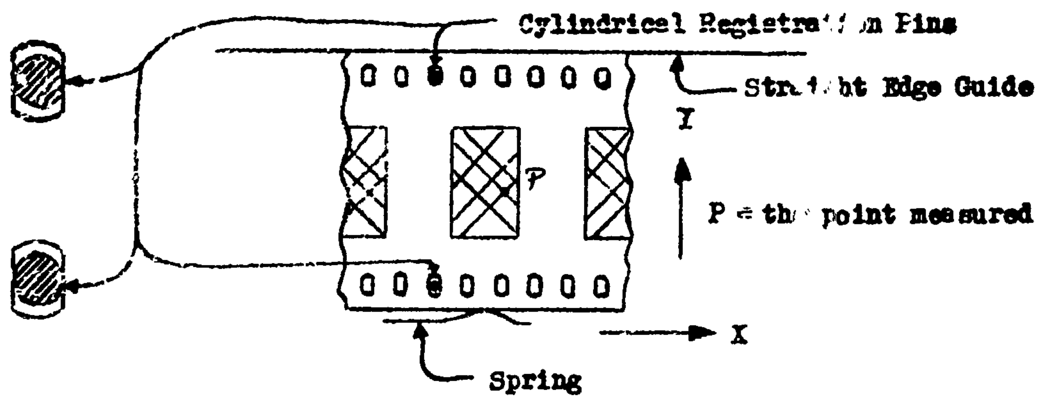


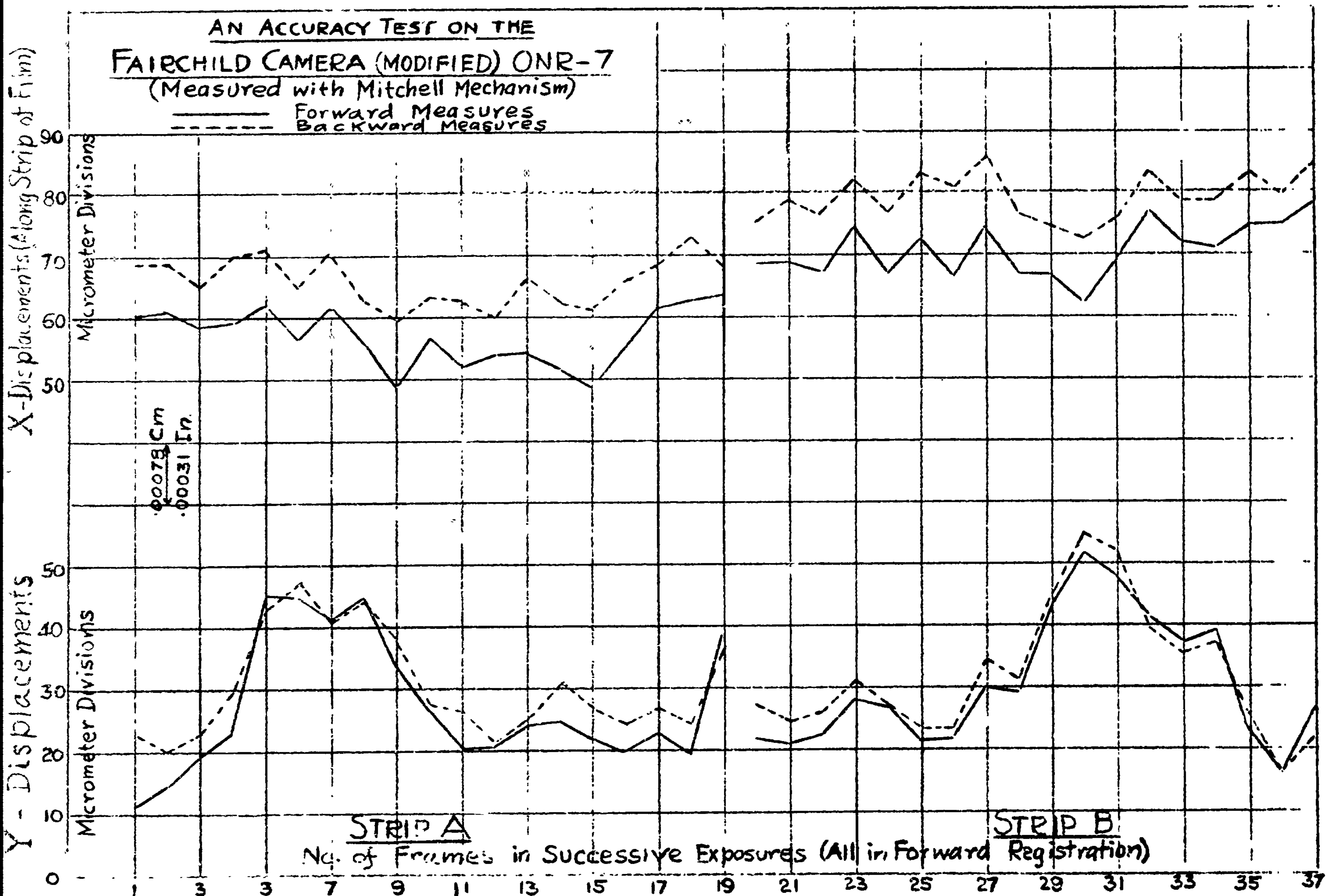
Figure 1a

However, along the Y-direction there exists, in these cameras, a straight edge guide, against which the film is gently pressed by a small metal spring. This feature contrives to keep the film in good alignment as far as the Y-direction is concerned, but does not possess the positive advantages of the kinematic film location principles of the Mitchell Camera. The accuracy in this co-ordinate, therefore, depends both on the operation efficiency of the spring and on the tolerance limit of the width of the film from frame to frame, as well as the accuracy of preservation of the distance from the edge of the sprocket holes to the edge of the film. Its accuracy of re-positioning the film in any given projector gate will depend much on the location, size and adjustment of the guide and pressure spring, unlike the Mitchell (or Bell and Howell) cameras.

Advancement of the film between exposures was done by the actuators of the Fairchild camera, which were operated in one case by a motor and in the other by a solenoid, each controlled by appropriate switches.

To compare the results of our first test (1*) it would be better if we could use the same camera both for exposure and measurement, as we did with the Mitchell mechanism; the interpretation of results would then be much simpler. However, it is not possible to do so with our present measuring device, and since our final use of the apparatus for the analysis of films will be made with a measuring Mitchell mechanism anyway, we decided to do the measurements with the Mitchell mechanism. Moreover, the accuracy of the latter instrument has already been investigated, but, of course, the positioning system

(1*) Loc. cit.



AN ACCURACY TEST ON THE
FAIRCHILD CAMERA (MODIFIED) ONR-7
(Measured with Mitchell Mechanism)
Forward Measures
Backward Measures
X-Displacements (Along Strip of Film)
Micrometer Divisions
90
80
70
60
50
.00078 Cm
.00031 In.
Y - Displacements
Micrometer Divisions
50
40
30
20
10
0
STRIP A
STRIP B
No. of Frames in Successive Exposures (All in Forward Registration)
1
3
3
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37

FIGURE 1

of the Mitchell differs from that of the Fairchild camera. There seems no easy way to use the Fairchild camera for our measuring machine, however, so the preferred measuring procedure would really be of academic interest only. We could not have had any hope of positioning except for the fact that the Fairchild cameras do most of their positioning on the same sprocket holes used for the theoretically sounder positioning scheme of the Mitchell camera.

III. RESULTS ACHIEVED.

For these tests we threaded the films taken in the Fairchild camera into the Mitchell mechanism, and then measured the displacement of a point exposed onto the film in the Fairchild camera from frame to frame by means of a filar micrometer microscope mounted rigidly with reference to the Mitchell mechanism. Two series of measurements were made, one in the forward direction and one in the backward direction of the Mitchell mechanism, both in the X and Y co-ordinates.

The results are plotted in Figure 1 and summarized in Table I for the modified camera. Those of the unmodified camera are plotted in Figure 2 and summarized in Table II.

TABLE I - MODIFIED CAMERA

Film Strip	Co-or.	Direction of Measurement	Mean Position (Micrometer Readings)	Range (Micrometer Division)	Range Inches	Average Deviation (Micrometer Divisions)	Average Deviation Inches
A	X	Forward	57.15	13.6	.00042	3.98	0.000123
		Backward	66.06	13.5	.00042	3.16	0.000098
	Y	Forward	27.22	34.6	.00107	9.03	0.000280
		Backward	30.52	27.2	.00084	7.10	0.000220
B	X	Forward	70.80	16.1	.00050	3.53	0.000110
		Backward	79.18	12.8	.00040	3.18	0.000099
	Y	Forward	30.83	35.5	.00110	8.42	0.000261
		Backward	32.11	39.1	.00121	8.23	0.000255

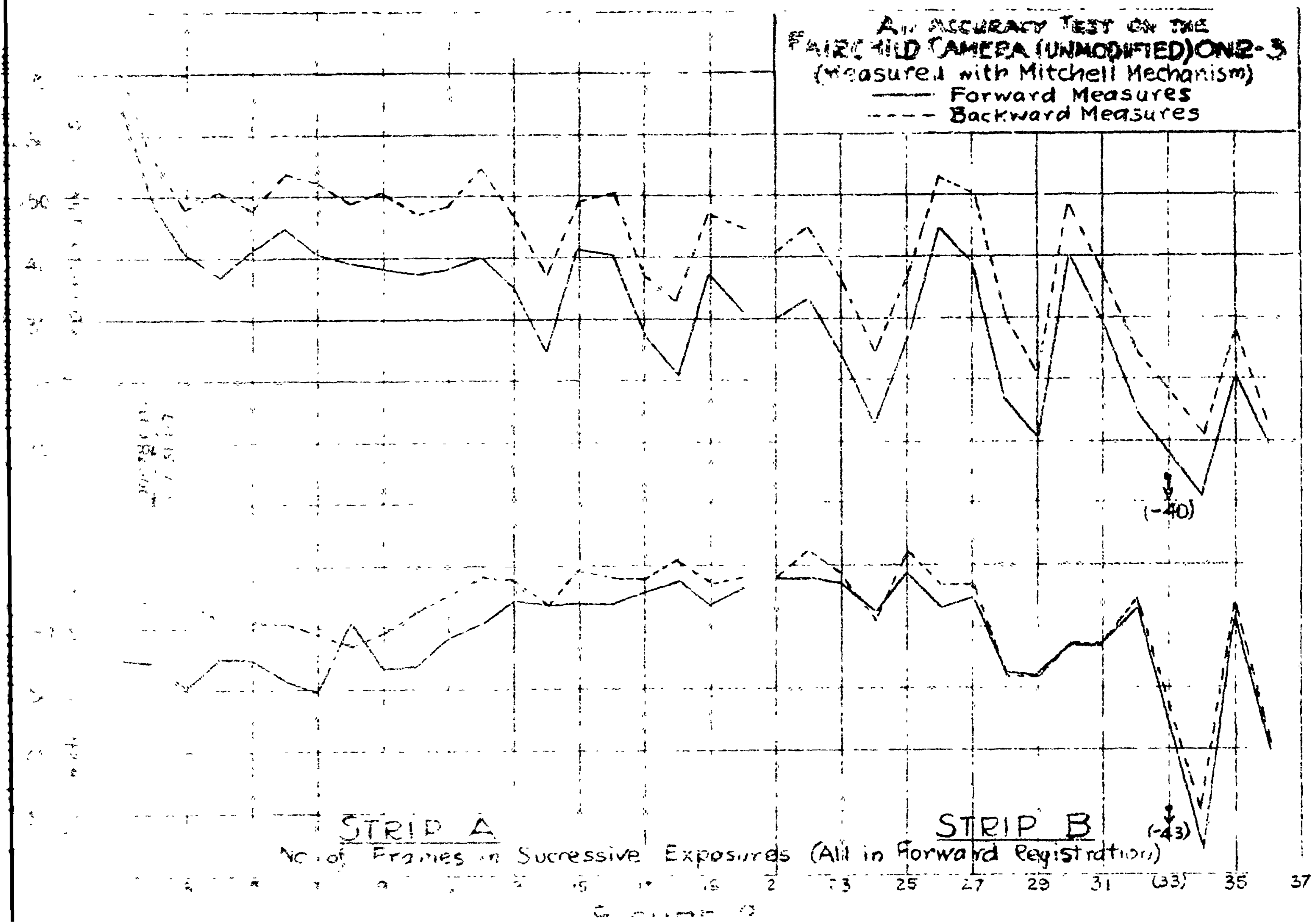

An Accuracy Test on the
Fairchild Camera (Unmodified) ON2-3
(Measured with Mitchell Mechanism)
—— Forward Measures
- - - - Backward Measures
(-40)
(-43)
STRIP A
STRIP B
No. of Frames in Successive Exposures (All in Forward Registration)
25
27
29
31
(33)
35
37
50

TABLE - II - UNMODIFIED CAMERA

Film Strip	Co-or.	Direction of Measurement	Mean Position (Micrometer Readings)	Range (Micrometer Divisions)	Range Inches	Average Deviation (Micrometer Divisions)	Average Deviation Inches
A	X	Forward	38.60	44.8	.00139	5.76	0.000179
		Backward	49.03	38.[illegible]	.00129	5.07	0.000157
	Y	Forward	59.02	17.2	.00053	5.28	0.000164
		Backward	64.73	13.8	.00043	3.13	0.000097
B	X	Forward	23.48	41.4	.00128	10.41	0.000316
		Backward	33.47	41.5	.00128	10.76	0.000334
	Y	Forward	58.11	44.0	.00136	8.73	0.000270
		Backward	59.48	42.5	.00132	9.15	0.000284

In Figures 1 and 2, the abscissas represent the successive numbers of frames from one end of the film to the other. All films were exposed in the normal forward direction in the Fairchild camera. The ordinates give the micrometer readings on the spot impressed upon the film in the Fairchild camera. Measurements in the forward direction of the Mitchell mechanism are shown by full lines, those in the reverse direction by dotted lines. The length of the arrow designates the scale of the figure, being equivalent to 0.00078 cm. or 0.00031 inch per line of the large grid. Thus these curves show the variations of the measured points from frame to frame both for the X- and Y- coordinates, and therefore give an idea of the accuracy of the quantity we seek.

The mean position, range, and average deviation, as summarized for all cases in Tables I and II, are defined and derived respectively as follows: (1) The "mean positions" tabulated are the arithmetical means of the readings of the micrometer for all the frames taken in the stated direction of measurement. (2) The "range" is the total range, obtained by taking the difference between the highest and lowest readings for any two frames measured in the directions shown. (3) The "average deviation" is the average, without regard to sign, of the deviations (positive and negative) from the mean position for all the frames measures in the given directions. Both the "range" and the "average deviation" constitute a significant measure of the accuracy of the instrument for our purposes.

IV. DISCUSSION OF RESULTS.

The data shown in the foregoing section are the combined results of registration with the Fairchild and of measurement with the Mitchell mechanism, and not of the Fairchild camera alone. The data therefore contain the accuracy and design factors of both instruments. Hence in the discussions below, this fact should be kept in mind. As was pointed out, if our final reduction of films is to be made with this combination, our test procedure is directly significant to our problem. We shall therefore not attempt to separate the involved factors.

A. The Modified Camera

The performance of the modified camera is substantially superior to that of the unmodified. The wandering of the points in Figure 1 is similar for both directions of the Mitchell mechanism, as one would expect. The wanderings thus result either from positioning errors of the Fairchild mechanism, or from dimensional differences from place to place along the length of the film material, which the design differences between the cameras make it impossible to eliminate from the results. To ask the film manufacturer to hold these dimensional differences down to acceptable limits in terms of our test and to avoid differential processing effects is unfeasible. However, the magnitude of the errors of this origin is not so large as to rule out limited use of the modified camera for the intended purpose. The X average deviations fall comfortably within the specified limits of 2×10^{-4} inches. and the Y average deviations fall at within $1\frac{1}{2}$ times the specified limits. The difference between the largest and smallest values of X or Y for a run in a given direction, which we have called "range", also falls within our established limits of 6×10^{-4} inches for X, but goes consistently to about $1\frac{1}{2}$ to 2 times our limit for Y.

The Mitchell mechanism, as one would expect, shows a much better performance, and falls generally well within our specifications. The test of the Mitchell camera also involved an exposing run and a measuring run, while the Fairchild camera was subjected only to a single exposing run through its mechanism. The test of the Mitchell camera was therefore more stringent. On the other hand we are able to make no satisfactory separation of errors arising from the inaccuracy of operations of the Fairchild camera and those arising from dimensional fluctuations in the film.

The film advance mechanism, even in the modified Fairchild camera, exerts a substantial pressure on the registration sprocket holes as the claw moves back from its fully advanced position to the position for a new stroke. It may be that this force enlarges the sprocket holes slightly and produces the difference of X for forward and reverse runs in the Mitchell Mechanism. Or it may be that the course of this effect is enlargement of the holes by the Fairchild positioning pins. Or it may be from some other undiscovered cause. It will not adversely affect our planned measurement because they can readily be carried out in a single direction of film motion.

In describing the usefulness of the Fairchild Camera for this application we should mention that while wholly satisfactory for the purpose for which the Fairchild camera was developed, the film advance and positioning apparatus cannot be expected to give performance of highest possible registration standards. Because the film has a straight guide at its one edge against which it is spring loaded, the two following conditions must apply precisely, or the over-constraint of the film being positioned in its plane can only be accommodated by elastic (or worse still inelastic) deformation of the film:

(1) The positioning pins must lie precisely on a line perpendicular to the straight edge guide.

(2) The film edge must be accurately perpendicular to the registration sprocket holes at each registration position.

In the X-coordinate, the slight slope as shown by the curves from one end of the film to the other, indicates again the probably differential shrinkage of the film; this is a feature also noted in our former analysis. This probably results from the shortness of the strips used in our test, and will not show up in long movie runs, we expect.

B. The Unmodified Camera

The data for this camera can be seen in Figure 2 and Table II. By comparing these with those of the modified camera (Figure 1 and Table I), it is evident at once that the registration accuracy of this camera in the unmodified form is very much less. The average deviation of Strip A in X-coordinate is about 50% bigger, and that of Strip B is over three times as much. In the Y-coordinate, the figures are comparable, probably a direct result of the straight edge guide in this coordinate.

Besides the general decrease of accuracy in this instrument, there are also present certain erratic behaviors which may result from the large impulses applied by the solenoid drive. For instance, Frame No. 53 in Strip B is so much displaced that the measured point can not even be located inside the figure. This point falls so far out that it was discarded in the derivation of our results

As in the case of the modified camera, the slope due to differential shrinkage of the film appears again in the figure

V. RECOMMENDATIONS.

From the discussions presented above, we see that the Fairchild mechanism, in its modified form, although less accurate than the Mitchell instrument, is good enough for a least a part of our purposes as a registration camera. Use of the Mitchell mechanism as a measuring or projection apparatus, and the Fairchild camera for exposing the film provides us a reasonably suitable combination of instruments for photographing and analyzing solar prominence records. A Bell and Howell type exposing camera would undoubtedly be vastly superior in registration and operation to the Fairchild camera, but the cost of such cameras probably substantially exceeds the cost of the Fairchild cameras, even including the cost of modifications. Also the Fairchild camera offers some advantages of compactness and light weight. We plan, in the future to do some tests on the Bell and Howell type mechanism.

VI. ACKNOWLEDGEMENTS.

I wish to express my thanks to the personnel of the Physics Instrument and Research Laboratory for their assistance in these tests and in the modification of the Fairchild camera. These modifications were supervised by Dr. Walter Orr Roberts, but the detailed designs were produced at the Physics Instrument and Research Laboratory. Dr. Roberts also assisted in the planning of the tests and in their interpretation as reported here.

Ching-Sung Yü

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December 1, 1949

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Walter Orr Roberts

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